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Technical Report 570

AN INVESTIGATION OF GEOMETRIC RADAR SHAPES FOR STEREOTYPING

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U. S. Army
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This investigation sought to determine whether any of the symbols which are currently being used or are proposed for usage in future air defense systems are stereotyped with the meanings hostile, friendly, and unknown.

Each of the 100 male service members sorted 60 shapes into four categories, namely friend, hostile, unknown, and other depending upon what each shape connoted. The personnel also rank ordered the shapes which had been

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sorted into the first three categories. Chi square statistics were used to analyze the data.

Shapes were identified which are stereotyped with the three meanings. The 5-Pointed Star, Heart, and Flag were associated with the friend meaning. The Swastika and Question Mark were associated with the hostile and unknown meanings respectively.

The results of this experiment will be utilized in future research which will be aimed at deriving a standard symbology for application to radar assisted air defense systems.

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AN INVESTIGATION OF GEOMETRIC RADAR SHAPES FOR STEREOTYPING

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FOREWORD

The Army Research Institute for the Behavioral and Social Sciences (ARI) is performing research in support of a project entitled "Human Factors in System Development and Operations". This program is directed at the development of a technological base which will support development, evaluation and application of improved doctrine, work methods and system design concepts to enhance operator/user performance in military systems. The ARI Field Unit at Fort Bliss, Texas has a work unit, "Analysis of Operator Symbology in Air Defense", under this major research effort, which is aimed at deriving a standard symbology for radar assisted air defense systems.

The research described in this report had the objective of determining whether any of the symbols which are currently being used or are proposed for usage in future air defense systems are stereotyped with the meanings hostile, friendly, and unknown. Other shapes which have been studied in discriminability studies were also investigated.

This research was performed under Army Project 2Q762722A765 and is responsive to the needs of the U.S. Army Air Defense School, Directorate of Combat Developments, Fort Bliss, Texas.

JOSEPH ZEIDNER
Technical Director

AN INVESTIGATION OF GEOMETRIC RADAR SHAPES FOR STEREOTYPING

EXECUTIVE SUMMARY

Requirement:

To investigate the extent to which symbols currently used or proposed for future air defense systems are stereotyped with the meanings hostile, friendly, and unknown.

Procedure:

One hundred fire control crewmen participated in the experiment. They sorted 60 shapes into four categories, namely, friend, hostile, unknown, and other. Participants placed the shapes which connoted friend, hostile, and unknown into their applicable categories. Those shapes associated with any other meaning were put into a separate (miscellaneous) pile. After the shapes were sorted, each participant rank ordered the symbols in each of the first three categories. Data were analyzed by Chi square statistics.

Findings:

Results from the sorting task showed:

a. The 5-Pointed Star, Heart, Flag, Circle, and Cross were associated with the friend meaning.

b. The Swastika, Collapsed Square, and "X" were associated with the hostile meaning.

c. The Question Mark, 3-Sided "U", and 6-Sided "U" were associated with the unknown meaning.

Data analyses from the rank ordered shapes identified the following:

a. The 5-Pointed Star, Heart, and Flag were strongly associated with the friend meaning.

b. The Swastika was strongly associated with the hostile meaning.

c. The Question Mark was strongly associated with the unknown meaning.

Utilization of Findings:

In future research stereotyped symbol sets will be evaluated in mixed displays which approximate an air defense radar console screen at a moderate saturation level. The research will vary the level of simulation fidelity and identify sets of stereotyped symbols which are highly discriminable.

AN INVESTIGATION OF GEOMETRIC RADAR SHAPES FOR STEREOTYPING

CONTENTS

LIST OF TABLES

LIST OF FIGURES

AN INVESTIGATION OF GEOMETRIC RADAR SHAPES FOR STEREOTYPING

Introduction

The Army Research Institute for the Behavioral and Social Sciences has initiated a research program aimed at deriving a standard symbology for radar assisted air defense systems. This report describes the first step in the research.

Rationale for Standardization

Radar displays present processed video in the form of monochromatic geometric shapes. Each of these shapes has assigned to it a meaning such as enemy, friendly, or unknown. A radar console operator's main tasks are to monitor the display and respond differentially to the shapes when necessary.

When cathode-ray tubes (CRT) first started displaying synthetic information, only a few geometric shapes could be generated and these available shapes were assigned meanings. As the hardware became more sophisticated and could create additional shapes, the situation changed. Unfortunately these changes did not take place in an orderly fashion because new meanings were assigned to earlier shapes. This practice has continued over the years, and even now, each contractor who develops a radar system constructs a set of shapes and designates its meaning for display use.

Each of the current Army air defense systems (AN/TSQ-51, AN/TSQ-73, Nike-Hercules, IHAWK, PATRIOT, ROLAND, and DIVAD Gun) has a unique set of geometric symbology. These sets not only have different symbols, but, when identical shapes are employed in different systems, they may represent diametrically opposite and contradictory information. For example, a circle represents a friend in the AN/TSQ-73 system and a foe in the IHAWK system.

The different symbologies cause no problems as long as a radar console operator continues working with only one system. However, symbol confusion results when ancestral systems are replaced and personnel must be retrained and reassigned to a new system.

Stereotyping

Ciccone, Samet, and Channon (1979) prescribed three guidelines for symbol design. They were as follows:

a. Take advantage of the user group's prior learning and conditioning to select symbol features which enhance association formation.

b. Minimize, to the extent possible, the amount of feature similarity among different members of a symbol set.

c. Minimize the visual saliency of those features that must remain redundant across members of a symbol set.

Two specific rules for choosing geometric shapes for specific applications were stated by Van Cott and Kinkade (1972) and McCormick (1976). They were:

a. Shapes should be compatible and have association value with the coded objects.

b. Only shapes which are highly discriminable should be used.

Many experiments on discriminability have been conducted (Casperson, 1950; Sleight, 1952; Gerathewohl and Rubinstein, 1953; Harris, Green, Wilson, and Liaudansky, 1956; Bowen, Andreassi, Truax, and Orlansky, 1959; Davis, 1969). Honingfeld (1964) gave a thorough review of the literature in this area. However, very little research has been done on the former rule and the concept of stereotyping in relationship to geometric radar symbology.

The most quoted study on radar symbology stereotyping was presented by Torre and Sanders (1958). They investigated the possibility that particular shapes in our population may be stereotyped with the meanings hostile, friendly, and unknown. Their one-hundred enlisted men invented one symbol for each meaning. Conclusions included the following:

a. Open straight-line forms are associated with the hostile meaning.

b. Closed forms are associated with the friendly meaning.

c. Curved-line forms are associated with unknown meaning.

The same stimulus words were examined in an experiment consisting of a paired comparison paradigm (Davis, 1969). Twenty-three shapes, chosen from various sources, were arranged into 253 pairs and presented to twenty technical employees from her laboratory. Each person was shown pairs of symbols, along with one of the three words, and selected the symbol which most closely matched the meaning. Results were:

a. Simple enclosed forms tend toward a friendly meaning.

b. Open angular straight-line forms are strongly associated with the hostile meaning.

c. Complex curved-line forms both open and closed lean toward the unknown meaning.

Davis (1968) hypothesized that stereotyping is dependent upon two factors: selectivity and primacy. She defined selectivity as the assignment of a shape to a particular meaning. Primacy was defined as a measure of shape strength. It is derived by rank ordering the shapes assigned to a specific meaning. The hypothesis was only partially substantiated in her research.

The purpose of the present experiment was to determine whether any of the symbols which are currently being used or are proposed for usage in future air defense systems are stereotyped with the meanings hostile, friendly, and unknown. Other shapes which have been studied in discriminability studies were also investigated. The stereotyping of shapes was evaluated in terms of the selectivity and primacy of meanings assigned to each shape. The investigation also evaluated whether symbol stereotyping would differ as a function of the type and level of console operator experience.

Method

Subjects

One-hundred male radar console operators, E1 through E6, stationed at Fort Bliss, Texas participated in this experiment. Fifty possessed the 16C, Nike-Hercules Fire Control Crewman, Military Occupational Speciality (MOS), while the others had 16E, HAWK Fire Control Crewman, MOSs. Half of the crewmen in each MOS were recent graduates of Advanced Individual Training (AIT); the others had field experience.

Apparatus

The stimuli were the 60 shapes pictured in Figure 1. They were a composite of: symbology used in systems currently in the Army air defense inventory and in the procurement cycle and simple shapes which have been used in stereotyping and discriminability studies and which can be generated by current hardware for presentation on CRT and/or plasma displays. Table 1 shows the shapes selected from air defense systems and their source, while Table 2 presents additional shapes chosen from stereotyping and discriminability studies. The shapes were printed in black ink and centered on 3 X 5 inch cards. Each shape was drawn so that it could be as large as possible, yet still be encompassed by a one-inch circle.

Procedure

The experiment followed a modified Thurstone (1927) sort procedure. Each subject was given a shuffled deck of 60 cards and instructed to go through it and sort the shapes into four categories, namely, friend, hostile, unknown, and other. (The fourth category was included to remove the need for an absolute choice). The subjects were told to place the cards which connoted friend, hostile, and unknown into their applicable categories. Those cards which were associated with another or no meaning were put into a miscellaneous pile. After the deck had been sorted, each subject was instructed to go through and rank order the symbols in each of the first three categories, according to the degree to which they fit the stereotyped meaning.

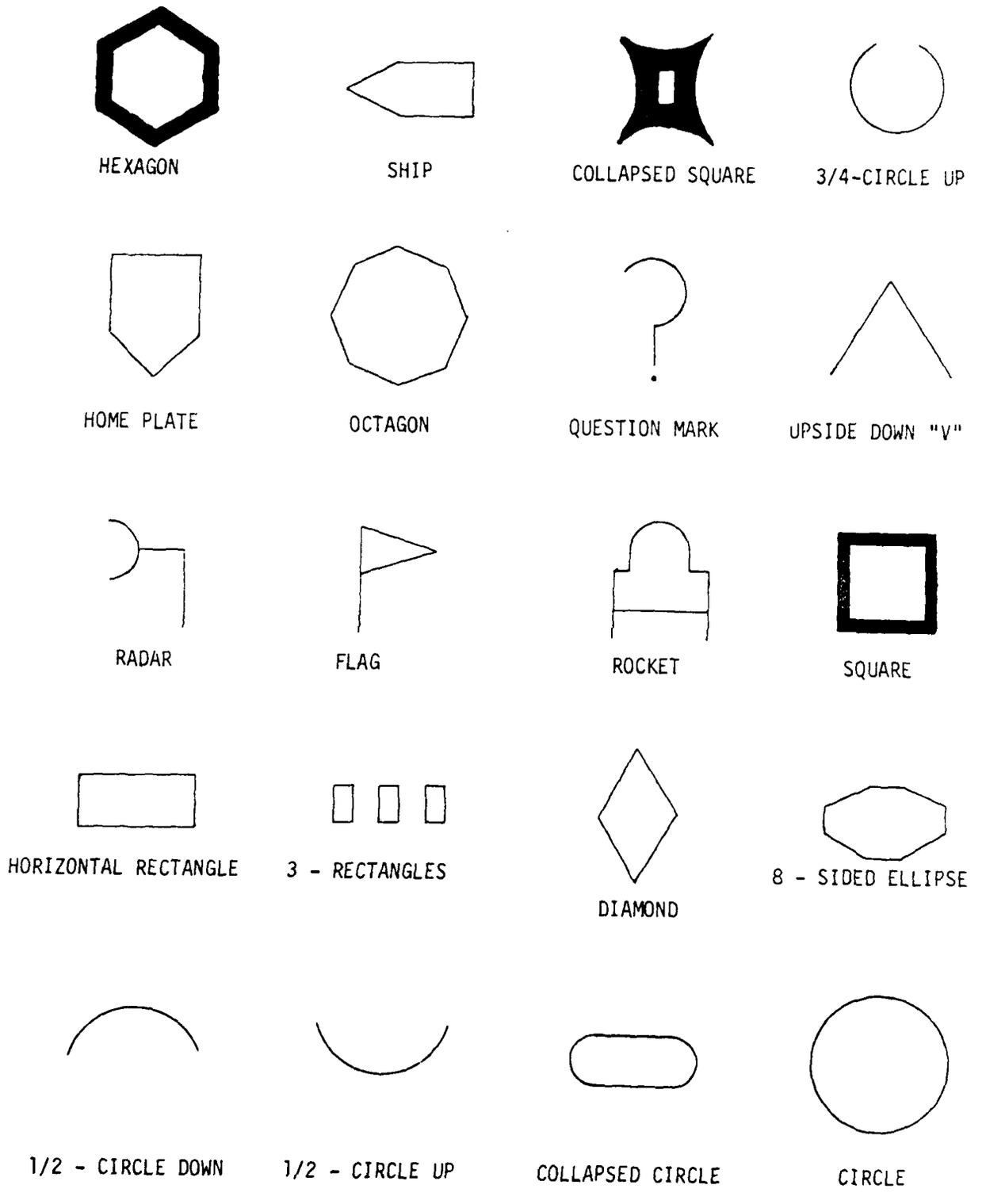

Figure 1. The 60 shapes examined in the investigation.

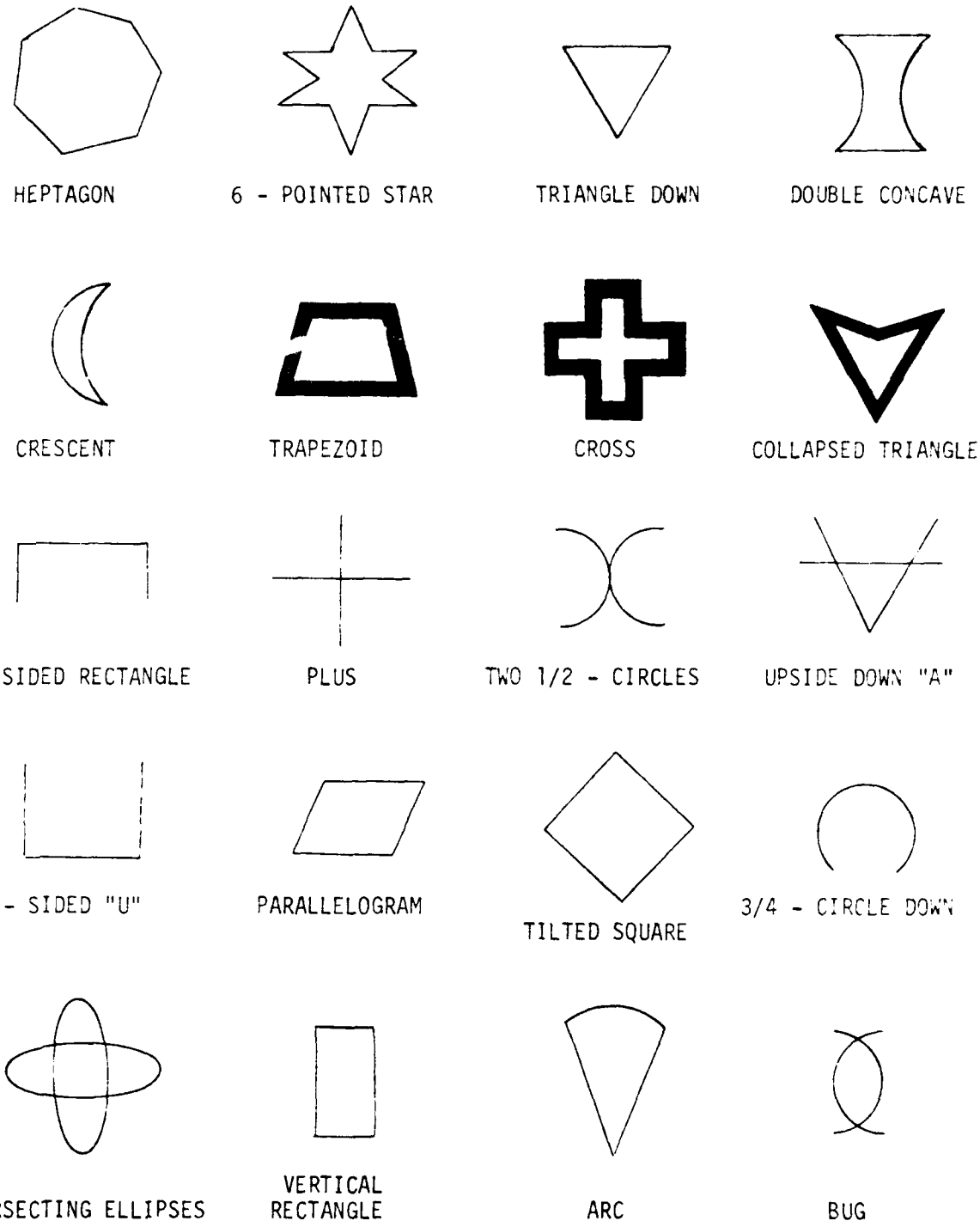

Figure 1 (continued). The 60 shapes examined in the investigation.

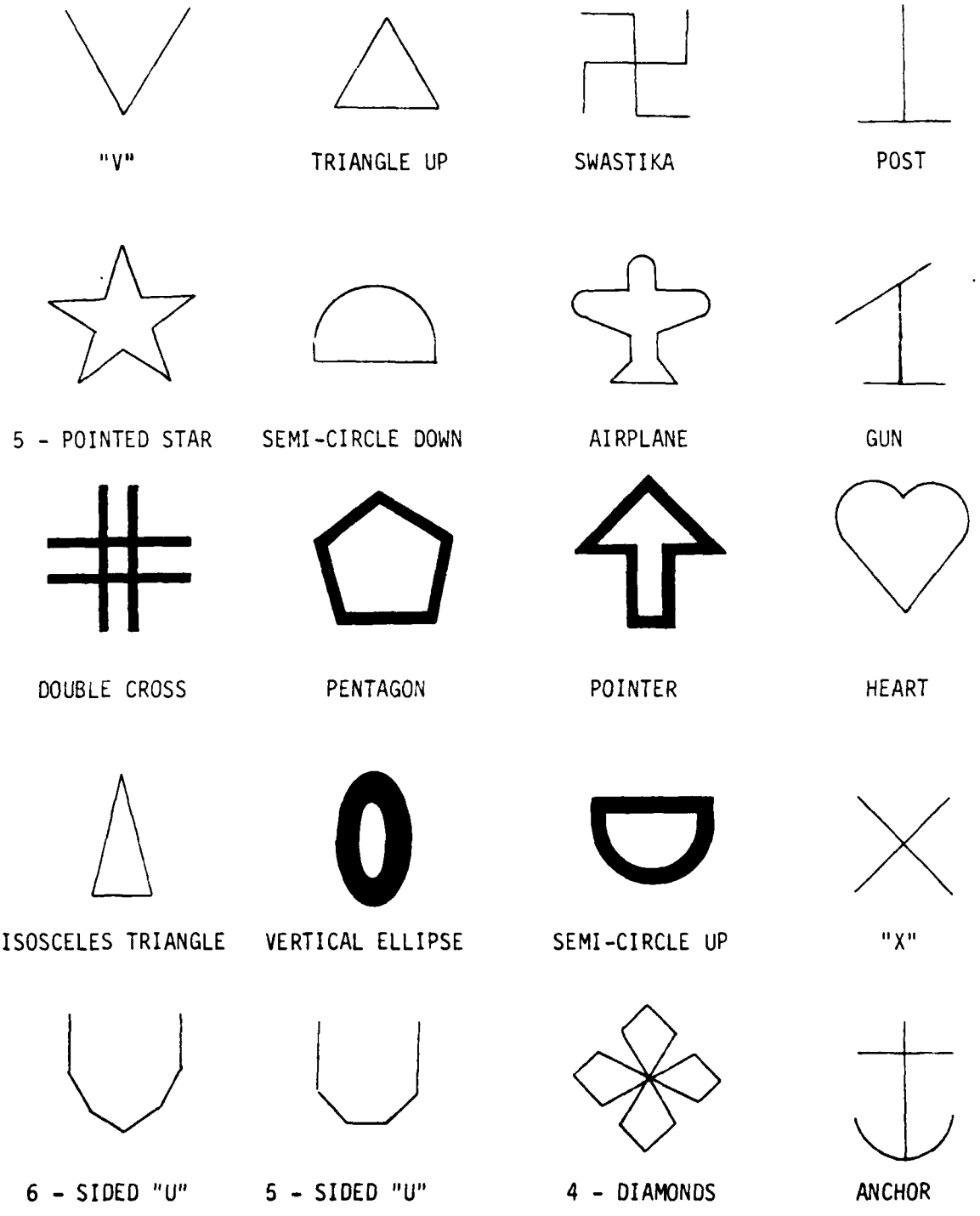

Figure 1 (continued). The 60 shapes examined in the investigation.

Table 1

Stimuli Selected from Air Defense Symbology

Shape	Symbologies						
	AN/TSQ-51	AN/TSQ-73	Nike-Hercules	HAWK	ROLAND	PATRIOT	DIVAD Gun
Hexagon						X	
3/4-Circle Up			X				
Square				X			X
Horizontal Rectangle					X		X
3-Rectangles					X		
Diamond		X				X	
8-Sided Ellipse		X					
1/2-Circle Down			X	X			
1/2-Circle Up			X	X			
Collapsed Circle	X		X	X			
Circle	X	X	X			X	X
3-Sided Rectangle							X
Plus							X
Two 1/2-Circles							X
Upside Down "A"						X	
3-Sided "U"		X					
Tilted Square	X						
3/4-Circle Down			X				
Intersecting Ellipses				X			

Table 1 (Continued)

Stimuli Selected from Air Defense Symbology

Shape	Symbologies						
	AN/TSQ-51	AN/TSQ-73	Nike-Hercules	IHAWK	ROLAND	PATRIOT	DIVAD Gun
Verticle Rectangle				X			
Verticle Ellipse						X	
"X"		X					
6-Sided "U"		X					
5-Sided "U"	X						
4-Diamonds		X				X	

Note. X means that the shape has been selected from the air defense symbology

Table 2

Stimuli Selected from Stereotyping and Discriminability Studies

Shape	Studies						
	Casperson (1950)	Sleight (1952)	Geranthewohl Rubinstein (1953)	Harris et al (1956)	Torre + Sanders (1958)	Bowen et al (1959)	Davis (1969)
Ship		X					
Collapsed Square						X	
Home Plate						X	
Octagon		X					
Question Mark					X		
Upside Down "U"							X
Radar				X			
Flag				X			
Rocket				X			
Heptagon		X					
6-Pointed Star	X	X					
Triangle Down				X			X
Double Concave		X					
Crescent		X					
Trapezoid		X	X			X	
Cross	X					X	
Collapsed Triangle						X	
Parallelogram			X				
Arc							X

Table 2 (Continued)

Stimuli Selected from Stereotyping and Discriminability Studies

Shape	Studies						
	Casperson (1950)	Sleight (1952	Geranthewohl Rubinstein (1953)	Harris et al (1956)	Torre + Sanders (1958)	Bowen et al (1959)	Davis (1969)
Bug							X
"V"							X
Triangle Up	X	X	X	X	X	X	
Swastika		X					
Post				X			
5-Pointed Star					X	X	
Semi-Circle Down		X					X
Airplane		X					
Gun				X			
Double Cross				X			
Pentagon		X				X	
Pointer						X	
Heart		X					
Isosceles Triangle	X						
Semi-Circle Up						X	
Anchor				X			

Note. X means that the shape has been selected from the stereotyping and/or discriminability study.

Statistical Treatment

Information gathered from the sorting and rank ordering tasks was treated separately. The data were analyzed by repeated applications of Chi square statistics.

Sorting. 1 X 2 Chi squares, assigned-not assigned, were performed on each of the 60 shapes to decide whether shapes had been assigned to the friend, hostile, and unknown categories, instead of the miscellaneous pile. To establish which of the shapes had been sorted into the friend, hostile, and unknown categories in an order other than random, 1 X 3 Chi square statistics were calculated on each of the remaining shapes. A series of three 1 X 2 Chi squares, friend-not friend, hostile-not hostile, and unknown-not unknown, were computed on each of the identified shapes to resolve where the differences existed in the sort.

Rank Ordering. To determine if any of the shapes had been rank ordered in a manner other than by chance into the first five positions within the three categories, 1 X 3 Chi square statistics were used on each of the 60 shapes. Three 1 X 2 Chi squares, friend-not friend, hostile-not hostile, and unknown-not unknown, were carried out on each of the rank ordered shapes to determine where the differences existed in the rank.

The data generated in the experiment were evaluated in three separate analyses. The first analysis addressed the console operators as a whole (Total group; N=100). The second compared the main effects of type of MOS and level of experience (Nike-Hercules and HAWK groups; AIT and Field groups; N=50). The third analysis consisted of investigating the interactions of MOS by experience level (Nike-Hercules-AIT, Nike-Hercules-Field, HAWK-AIT, and HAWK-Field groups; N=25).

Results

Sorting

Results from the analyses performed to decide whether shapes had been assigned to one of the first three categories instead of the miscellaneous pile showed the Collapsed Square, Question Mark, Circle, Cross, Plus, Intersecting Ellipses, Arc, Swastika, 5-Pointed Star, Heart, "X", and 4-Diamonds to be assigned to the friend, hostile, and unknown categories by all nine groups; the Gun was not assigned by any of the groups. The findings were significant at the .01 level. Table 3 displays the shapes which were sorted into the first three categories in an order other than random and significant at .01. The shapes identified at a $p \leq .01$ as the result of the successive application of three 1 X 2 Chi squares are detailed in Table 4.

Rank Ordering

The starting points for the data analyses of rank ordering were those shapes which had been sorted into the first three piles and rank ordered

Table 3

Shapes Sorted Into the First Three Categories

Shape	Groups								
	Total	Nike-Hercules	HAWK	AIT	Field	Nike-Hercules-AIT	Nike-Hercules-Field	HAWK AIT	HAWK Field
Hexagon			X						X
Ship	X	X	X		X	X	X		X
Collapsed Square	X	X	X	X	X	X	X	X	X
Home Plate	X		X						X
Question Mark	X	X	X	X	X	X	X	X	X
Radar	X	X	X		X		X		
Flag	X	X	X	X	X	X	X		
Rocket	X				X				
Horizontal Rectangle	X	X							
3-Rectangles					X				
8-Sided Ellipse	X				X				
1/2-Circle Up	X		X	X				X	
Circle	X	X		X	X	X	X		
Heptagon	X								
6-Pointed Star				X					
Triangle Down	X	X		X		X			
Double Concave	X	X							
Crescent	X	X	X		X		X		X
Trapezoid	X				X				X
Cross	X	X	X	X	X	X	X	X	
Collapsed Triangle	X	X				X			
3-Sided Rectangle	X	X			X		X		
Plus	X		X	X				X	
Upside Down "A"	X		X		X				X
3-Sided "U"	X	X			X		X		
Parallelogram					X				X
Tilted Square			X						
3/4-Circle Down	X	X							
Intersecting Ellipses	X	X	X	X	X		X	X	X
Verticle Rectangle	X								X

Table 3 (Continued)

Shapes Sorted Into the First Three Categories

Shape	Groups								
	Total	Nike-Hercules	HAWK	AIT	Field	Nike-Hercules-AIT	Nike-Hercules-Field	HAWK AIT	HAWK Field
Arc	X								
Bug					X				
Swastika	X	X	X	X	X	X	X	X	X
Post	X								
5-Pointed Star	X	X	X	X	X	X	X	X	X
Semi-Circle Down	X	X			X				
Airplane	X	X		X	X	X		X	
Double Cross	X	X		X				X	
Pointer		X		X		X			
Heart	X	X	X	X	X	X	X	X	X
"X"	X	X	X	X	X	X		X	X
6-Sided "U"	X		X	X	X			X	
5-Sided "U"					X				
4-Diamonds		X							
Anchor			X			X			

Note. X means that the shape was sorted by the group into the friend, hostile, and unknown categories in a systematic manner.

Table 4

Sorted Shapes Associated with Each of the Three Meanings

Shape	Groups								
	Total	Nike-Hercules	HAWK	AIT	Field	Nike-Hercules-AIT	Nike-Hercules-Field	HAWK AIT	HAWK Field
Ship		H							
Collapsed Square	H	H		H		H	H		
Question Mark	U	U	U	U	U	U	U	U	U
Flag	F	F		F		F			
Circle	F	F				F	F		
Trapezoid									U
Cross	F	F		F		F			
3-Sided "U"	U	U							
Parallelogram									U
Swastika	H	H	H	H	H	H	H	H	H
5-Pointed Star	F	F	F	F	F	F	F	F	F
Double Cross				H					
Heart	F	F	F	F	F	F	F	F	F
"X"	H		H	H		H		H	
6-Sided "U"	U		U	U				U	

Note. F means friend
H means hostile
U means unknown

into the first five positions of the friend, hostile, and unknown categories by 1/3 of the subjects. Table 5 identifies the shapes which were rank ordered into the first five positions in a manner other than by chance and were significant at .01. Table 6 presents the shapes which were found significant at the .01 level as a result of the analyses performed to determine where the differences existed in the rank order.

Discussion and Conclusions

The objective of the experiment was to determine whether any of the 60 shapes chosen from air defense symbology and stereotyping/discriminability studies are stereotyped with the meanings friendly, hostile, and unknown. Stereotyped shapes were identified by both the sorting and rank ordering procedures. The shapes derived by the two methods are detailed below.

Sorting. The 5-Pointed Star, Heart, Flag, Circle, and Cross were associated with the friend meaning. The Swastika, Collapsed Square, and "X" were associated with the hostile meaning. The Question Mark, 3-Sided "U", and 6-Sided "U" were associated with the unknown meaning.

Rank Ordering. The 5-Pointed Star, Heart, and Flag were associated with the friend meaning. The Swastika was associated with the hostile meaning. The Question Mark was associated with the unknown meaning.

The investigation examined the hypothesis that stereotyping is dependent upon two factors, selectivity and primacy. In this experiment the primacy factor was the principal element for symbol stereotyping since the symbols which were uncovered by the two procedures are identical to those arrived at by the rank ordering procedure alone.

Two other hypotheses investigated in the experiment were:

a. Different shapes would be selected by the two MOSs.

b. The two levels of experience groups would pick different shapes.

Some effects of MOS and experience level on stereotyping were found. Only four of the shapes identified by the Total group through the sorting procedure were selected by all MOS and experience groups. Also, two of the symbols uncovered by the rank ordering procedure were chosen by only one of the groups. However, four of the six shapes identified through both the sorting and rank ordering procedures were done so by all four groups, i.e., Nike-Hercules, HAWK, Field, and AIT. It thus appears that MOS and experience level had a minimal influence on stereotyping. As a result, subjects for future experiments will be able to be selected from a general air defense console operator pool without having to systematically vary MOS and experience. The present results suggest that the findings from future experiments should be generalizable to all air defense console operators.

Table 5

Shapes Rank Ordered Into the First Five Positions

Shape	Groups								
	Total	Nike-Hercules	HAWK	AIT	Field	Nike-Hercules-AIT	Nike-Hercules-Field	HAWK AIT	HAWK Field
Collapsed Square	X	X		X					
Question Mark	X	X	X	X	X	X	X	X	X
Flag	X	X		X	X		X		
Circle	X	X				X			
Cross	X	X	X	X	X				
Swastika	X	X	X	X	X	X	X	X	X
5-Pointed Star	X	X	X	X	X	X	X	X	X
Heart	X	X	X	X	X	X	X	X	X
"X"	X			X					

Note. X means that the shape was rank ordered by the group into the first five positions in a systematic manner.

Table 6

Rank Ordered Shapes Associated with Each of the Three Meanings

Shape	Groups								
	Total	Nike-Hercules	HAWK	AIT	Field	Nike-Hercules AIT	Nike-Hercules-Field	HAWK-AIT	HAWK-Field
Question Mark	U	U	U	U	U	U		U	
Flag	F				F				
Circle		F				F			
Swastika	H	H	H	H	H	H	H	H	H
5-Pointed Star	F	F	F	F	F	F	F	F	F
Heart	F	F	F	F	F	F	F	F	

Note. F means friend
H means hostile
U means unknown

Both of the previous radar symbology stereotype studies presented their conclusions in terms of certain configured forms being associated with the three meanings. The results of this investigation seem to follow most closely the patterns suggested by Torre and Sanders (1958). The 5-Pointed Star, Heart, Flag, and Circle are closed forms; the Swastika is an open straight-lined form; and the Question Mark is a curved-line form. Also of note, Torre and Sanders found the same 5-Pointed Star to be the symbol most representative of the friendly meaning, and the identical Question Mark to be most closely associated with the unknown meaning.

The overall objective of the research, of which this experiment was the first step, is to derive standard sets of geometric symbols for application to radar assisted air defense systems. The findings from the experiment will assure that the derived sets have stereotyped symbols. The results will be used to assemble symbol sets. These sets will be tested in mixed displays which approximate a console screen at a moderate saturation level. The purpose of the subsequent research will be to find sets of symbols which can be quickly and easily discriminated.

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